ART. IV.—*On the Occurrence of Striated Boulders in the Permo-Carboniferous Rocks near the mouth of the Shoalhaven River, New South Wales.*

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[Read 9th April, 1903.].

Since 1859, when Dr. A. R. C. Selwyn[1] recorded indications of ice action in the Inman valley, in South Australia, fresh evidence has been forthcoming from various sources, indicating widespread glacial conditions in the Permo-Carboniferous rocks of Australia. In Eastern Australia boulder beds exist as far north as the Bowen River Coalfield, Queensland,[2] and are well-known at several places in New South Wales,[3] notably at Branxton and Lochinvar; while in Victoria, the Bacchus Marsh[4] deposits are the most extensive and best-known among the somewhat numerous occurrences of smaller area in various parts of the State.

In Tasmania again, the glacial beds are widely distributed, being well-developed at Maria Island,[5] Little Peppermint Bay,[6] and at Wynyard.[7]

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1 "Geological Notes of a Journey in South Australia, from Cape Jarvis to Mount Serle." A. R. C. Selwyn, Parliamentary Paper, No. 20, Adelaide, 1859, p. 4.

2 "Report on the Bowen River Coalfield." R. L. Jack, F.G.S., p. 7, par. 39, Brisbane, 1879.

3 "Evidence of Glacial Action in the Carboniferous and Hawkesbury Series, in New South Wales." Professor T. W. E. David, B.A., F.G.S., Q.J.G.S., vol. xliii., pp. 190-196. "Glacial Action in Australia, in Permo-Carboniferous Time." Professor T. W. E. David, B.A., F.G.S., Q.J.G.S., vol. lii., pp. 289-301. "Discovery of Glaciated Boulders at the base of the Permo-Carboniferous System, Lochinvar, New South Wales." Prof. T. W. E. David, B.A., F.G.S., Jour. Roy. Soc. New South Wales, vol. xxiii., p. 154.

4 Note.—The papers on the Bacchus Marsh Deposits are extremely numerous. *c.f.* Note on the Bibliography of the Bacchus Marsh Deposits, by T. S. Hall, M.A., in the Victorian Naturalist, Melbourne, 1894, pp. 125-128; and a note also by A. E. Kitson, F.G.S., in his paper on the Glacial Beds at Wynyard, Tasmania. Proc. Roy. Soc. Vic., vol. xv. (n.s.), Pt. I., 1902, p. 30.

5 Note on Fossils from Maria Island, with evidence of glacial action consisting of huge ice-born erratics embedded in rocks of Permo-Carboniferous age. R. M. Johnston, F.L.S., Proc. Roy. Soc. Tas., p. 20, 1884. Notes on the Geology of Bruni Island. R. M. Johnston, F.L.S., Proc. Roy. Soc. Tas., pp. 18-26, 1886.

6 The Glacial Beds of Little Peppermint Bay, Tasmania. Prof. E. G. Hogg, M.A. Report of Secretary of Mines for Tasmania, 1900-1, and Proc. Roy. Soc. Tasmania, 1902.

7 On the Occurrence of Glacial Beds at Wynyard, near Table Cape, Tasmania. A. E. Kitson, F.G.S., Proc. Roy. Soc. Victoria, vol. xv., (n.s.), pt. i., 1902.

The rocks referred to in this paper occur along the New South Wales coast on the south side of the present outlet of the Shoalhaven River at Crookhaven. They form a small headland on which the Crookhaven lighthouse stands and also stretch a short distance southwards, as a somewhat broken line of low cliffs. Further south, the coast is low and stretches as a sandy beach for some miles, beyond which, again, the higher cliffs in the neighbourhood of Jervis Bay run out to sea. To the north of the Shoalhaven entrance, another stretch of sandy beach extends in the direction of Gerringong, where the well known fossiliferous tuff beds of Black Head form an important feature of the coast line.

The area under consideration is mapped as Permo-Carboniferous, and the late C. S. Wilkinson[1] in referring to this part of the coast line says "At Wollongong, Kiama, and on both sides of Jervis Bay, the marine beds of the Lower Coal Measures occur." The rocks consist of more or less horizontally bedded dark coloured argillaceous sandstones, but just to the south of the Crookhaven headland, there is a slight arch with the axis running out to sea, and a little to the north of this line, the marine platform is cut into by a channel, about half a chain wide, running more or less at right angles to the coast line and evidently due to the more rapid weathering of a dyke.

A small remnant of what appears to be portion of the igneous rock *in situ*, protrudes through the sand in the centre of the channel towards the shore end; it consists of a fine grained greenish grey rock.

The shore shingle consists of a great variety of rocks and an examination of the marine platform shows it to contain rocks of the same nature, embedded so firmly, that it was extremely difficult to extract them without injuring or breaking them. These boulders are of all sizes, from small pebbles up to blocks a foot or more in length; many are smoothed, but sometimes only on one or two sides, while in shape they are mostly irregular, often somewhat triangular and elongate. Various kinds of igneous and metamorphic rocks, such as porphyritic and granitic rocks, schists and quartzites were observed, but time did not permit of extensive collecting. A few likely boulders however were extracted and fortunately several showed distinct polishing, with

[1] Notes on the Geology of New South Wales. C. S. Wilkinson, F.G.S., F.L.S., Department of Mines, Sydney, 1882, p. 51.

grooving and striation on the underside; the others were so coated with oxide of iron, that any fine markings which may have been present were completely masked.

One of the best specimens consisted of a block of quartzite, which before removal measured over 12 inches along its greatest length; the top side was rough and irregular and it was rather badly jointed, so that it broke into several pieces on being chiselled out. The under side was polished, grooved and finely striated, while several of the sides were faced and imperfectly smoothed.

Further south again at Jervis Bay, in the neighbourhood of the small township of Huskisson similar beds occur, but the boulders were not so numerous and none of the few examined showed striation. Some large granitic blocks however were observed resting on the marine platform, and though these were not embedded they had evidently weathered out of the beds, for similar rocks of smaller size were seen *in situ*. The largest of these loose boulders measured, roughly, about 6 feet by 2 feet by $1\frac{1}{2}$ feet. The rocks here are fossiliferous, several spirifers, and a Platychisma being collected.

In 1861, somewhat similar features in rocks at Wollongong were described by the late Dr. T. Oldham[1], and the beds were compared with conglomerates in the Indian Talchir series, but no striated boulders were recorded, nor was ice-action suggested at the time to explain the origin of the formation. Later, however, the glacial origin of the Talchir beds was more fully worked out, and in 1885, Mr. R. D. Oldham,[2] A.R.S.M., of the Geological Survey of India, examined the New South Wales coal-bearing beds; he established the glacial origin of the conglomerates at Branxton, Wollongong and elsewhere, and confirmed the correctness of the previous correlation of the Australian Permo-Carboniferous beds with the Indian coal-bearing series and their associated boulder beds.

It appears then, that the presence of striated boulders in the beds at Crookhaven affords further evidence of the prevalence, in Permo-Carboniferous seas even in low latitudes, of floating ice, which, as it melted, dropped its load of stones on the muddy sea floor.

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1 Mem. Geol. Survey of India, vol. iii., p. 209.

2 Record Geol. Survey of India, vol. xix., pt. i., p. 44.